PROCESS AND APPARATUS FOR MAKING IMPROVED GLASS MICRO FIBERS

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ABSTRACT

A process is provided for producing improved, superior and more cost-effective glass micro fibers, wherein molten glass in filament form is attenuated into glass micro fibers by gasses of a combusted mixture of air and fuel. The improvement comprises introducing into the mixture a gas stream containing at least 70% by volume of oxygen. This avoids problems in glass micro fiber production where the quality of the fibers varies from time to time, as demonstrated by the quality of paper produced therefrom. An apparatus for producing the fibers is also provided, as well as improved glass micro fibers and improved papers made therefrom.
PROCESS AND APPARATUS FOR MAKING IMPROVED GLASS MICRO FIBERS

FIELD OF THE INVENTION

[0001] The present invention relates to a process and apparatus for making microfibers, and especially a process and apparatus that produces glass microfibers of uniform and improved quality, with greater cost effectiveness.

BACKGROUND OF THE INVENTION

[0002] In making glass microfibers, typically high temperature burners combust fuel to reach temperatures for melting glass and attenuating extruded streams of molten glass into glass microfibers. The velocity of the combusted fuel gasses impinging on the streams of molten glass causes attenuation of the molten glass streams to produce the glass microfibers. Most of the velocity of the gas stream is a result of the thermal expansion of the combustion gases due to the rapid rise in temperature inside the burner or combustion chamber.

[0003] However, it is known that the quality of glass microfibers varies from time to time, and that quality is most apparent in connection with the properties of papers made with those glass microfibers. While this problem with the glass microfibers has long been recognized, the art has not found either the reason for that variation in quality or a means of avoiding that variation in quality. The present invention centers around the discovery of the causes of that variation and a solution to the problems engendered thereby. Accordingly, the present invention, in one aspect thereof, provides improved, superior fibers, as compared to those of the prior art. In another aspect, the invention provides more cost effective fibers, as explained below.

[0004] In producing the glass microfibers, ambient air and fuel, e.g., petroleum fuel, especially natural gas, are drawn into a premix reservoir, gas train or directly into burners, or other combustion devices, disposed in a combustion chamber/fiberizing zone and the fuel is combusted for melting, drawing and attenuating the molten glass streams into glass microfibers. It is important to the economics of the process that the amount of air (oxygen) is essentially stoichiometric with the amount of fuel being combusted. If the amount of air (oxygen) is too little, incomplete combustion will result, normally referred to as operating in “rich” conditions. Then, as the combustion gases exit the burner, any uncombusted fuel will combust with secondary air that is aspirated into the fiberizing zone by the velocity of the flame. This secondary combustion has the effect of creating mini-explosions in the fiberizing zone, resulting in excessive turbulence that undesirably shortens the length of fibers being formed. It is known that poor glass microfiber quality will result when operating in rich conditions.

[0005] On the other hand, if the amount of air (oxygen) is in excess, unnecessary amounts of nitrogen (from the air) must be heated to the combustion temperature and expelled from the combustion chamber as part of the attenuating gas stream. This is normally referred to as operating in “lean” conditions. If this extra heating doesn’t occur, the velocity of the flame exiting the burner is reduced, limiting the ability of the flame/gasses to attenuate the glass streams into microfibers. To restore the necessary flame velocity, additional fuel/air mixture is normally added to the combustion chamber. This is a considerable waste of energy, and substantial excess air can make the combustion process, and hence the glass microfibers, uneconomical. The present invention avoids this difficulty, and, hence, provides a process that produces more cost effective fibers.

[0006] Therefore, considerable effort is made in the art to induce into the burners or combustion chamber only a stoichiometric amount of air, or slight excess thereof, in order to ensure complete combustion, but not have excess nitrogen (and other of the gasses of air) as a waste by-product. This ensures a maximum throughput of glass and, hence, fibers, through the process. To this end, substantial instrumentation is used to ensure that the volume of air induced into the combustion chamber is substantially stoichiometric with the amount of fuel fed to the chamber, either directly or through a premix gas train or reservoir.

[0007] However, as noted above, it is known that the quality of the glass microfibers that results from this process varies from time-to-time, as exhibited by the properties of paper produced from those glass microfibers.

BRIEF DESCRIPTION OF THE INVENTION

[0008] The invention is based on several primary discoveries and several subsidiary discoveries.

[0009] First, it was found that the quality of the glass microfibers deteriorated with the seasonal variations of the ambient air induced into the combustion burners. Stated another way, in more practical terms, it was found that, in general, the microfibers produced during the winter months were superior to the glass microfibers produced during the summer months, in terms of the quality of paper that could be produced from the respective micro glass fibers. This was completely unexpected.

[0010] Second, of the variables involved in the seasonal variations of ambient air, it was found that the variable most responsible for the deterioration of the quality of the glass microfibers is the moisture content of the ambient air. Typically, in the summer, the relative humidity of ambient air will be greater than in winter and a standard volume of air will have increased amounts of water. In certain regions the seasonal range of indoor relative humidity can be extreme. Inside the manufacturing plants, winter air, brought into the plant and heated, can be extremely dry, with relative humidity levels approaching zero. In the summer, relative humidity levels can approach 100%.

[0011] Like nitrogen, mentioned above, it was found that the humidity/water acts as a diluent, cooling the combustion process, and thus either increasing fuel requirements or reducing the efficiency of the fiberization process. Most importantly, and unlike nitrogen, it was recognized that water vapor is also a combustion product, and according to Le Chatelier’s Principle, increasing its concentration in the combustion zone will force the combustion reaction away from equilibrium, or in this case, away from complete combustion. This is a most important discovery. Therefore, in highly humid conditions, the glass microfiber production process will act like it is operating rich, even if the air/fuel ratio is perfectly adjusted. Resulting poor quality glass microfibers will, and do occur.

[0012] It was found that the only way to bring the equilibrium back in balance is to increase the concentration of
the non-fuel reactant, i.e., oxygen. Increasing the concentration of fuel is not a solution, since it would make the combustion conditions even richer. Increasing the reactants, i.e., fuel and air, stoichiometrically, would not shift the equilibrium because of the Le Chatelier’s Principle. Consequently, to achieve complete combustion in highly humid conditions, only the addition of additional oxygen, not just air, will avoid the problem of a shift of equilibrium because of the Le Chatelier’s Principle.

[0013] Thus, as further discovery, it was found that simply increasing the volume of air in the summer to compensate for the high humidity is not an effective approach to solving the problem. In addition to the above reason, increased volumes of air also introduces into the combustion process increased volumes of water vapor (thus increasing the problem noted above) and nitrogen, both of which must be heated to the combustion temperature during combustion and expelled from the process as waste stack gases. The resulting energy loss by simply increasing the volume of ambient air introduced into the combustion process is too great and renders the resulting process uneconomical.

[0014] As a result of the above discoveries, it was found that substantially pure oxygen could be introduced into the process. This avoids the equilibrium shift, discussed above, and energy loss by increased nitrogen and water vapor induced by additional ambient air but, at the same time, increases the oxygen content of the air to offset complete combustion. By this technique, combustion efficiencies rise, the proper temperature for uniform attenuation (fiberization) is reached, and excess heat loss is avoided in expelling excessive amounts of waste nitrogen and water vapor. Also, this maximizes the through-put of glass and, hence fibers, in the process, which increases the cost effectiveness of the process.

[0015] It was further found that with today’s technology, oxygen could be generated at the site of a combustion chamber in a most economical manner and fed directly into the process. This makes control and operation of the process quite easy and economical.

[0016] Further, this approach avoids the result of a “storing” amount of oxygen in the combustion mixture during the summer when additional ambient air is introduced into the combustion process, which results in excess and uncombusted fuel combusting downstream of the combustion chamber and the attenuation zone of the fiberizer, which causes an unstable attenuation of the glass streams, as described above. The unstable attenuation can result in shortened and unwanted fibers, which, again, is apparent from the deteriorated paper produced from such fibers.

[0017] Thus, in summary, the present invention provides a process for producing improved and more cost effective glass micro fibers, wherein molten glass in filament form is attenuated into glass micro fibers by gases of a combusted mixture of air and fuel, the improvement comprising introducing into the mixture a gas steam containing at least 70% oxygen. Correspondingly improved fibers and papers made therefrom are also provided.

[0018] The present invention also provides a fiberizer apparatus for producing improved, superior and more cost effective glass micro fibers comprising a premix device for combining ambient air flowing from an ambient air inlet and fuel flowing from a fuel inlet, an oxygen analyzer for analyzing an oxygen content of the combined air and fuel in the premix device, an oxygen generator for generating oxygen and flowing the generated oxygen to the premix device, a controller for adjusting the flow of oxygen from the oxygen generator to the premix device in response to signals generated by the oxygen analyzer so as to provided the mixture with at least 22% by volume of oxygen, and a burner for combusting the mixture into a flame in a former tube device for drawing and attenuating primary filaments of molten glass into glass micro fibers.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0019] FIG. 1 is a diagrammatic illustration of a form of the apparatus for carrying out the process of the invention.

[0020] FIG. 2 is a diagrammatic illustration of a preferred form of a sparger arrangement for injecting oxygen into the process.

**DETAILED DESCRIPTION OF THE INVENTION**

[0021] The invention involves enriching ambient combustion air, or ambient air in an ambient air/fuel mixture, for use in a combustion process for fiberizing molten glass streams into glass micro fibers, to between 22 and 35 volumetric % oxygen, by adding substantially pure oxygen, e.g., at least 70% pure oxygen, to the air or air/fuel mixture. That introduction is, preferably by way of the special spargers, described more fully below, or other means. The important point is the introduction of the substantially pure oxygen into the combustion process to avoid production of inferior micro fibers, as described above, and, thus, provide improved, superior and more cost effective fibers.

[0022] The oxygen may be obtained from any desired source, but commercially available “packaged” systems are preferred, e.g., PSA (Pressure Swing Adsorption) or VSA (Vacuum Swing Adsorption) systems. This is because they may be placed near a conventional combustion chamber/fiberizer apparatus and easily generate the required amounts of oxygen in sufficient purity. For example, OGS Company has available multi-ton oxygen generators with outputs of from 1250 to 5000 SCFH capacities. The units are available with telemetric communication packages so that they can easily be controlled to provide the required amount of oxygen at variable rates in response to process needs. Depending on ambient conditions like relative humidity and temperature, the oxygen generator, through storage tanks, will supply oxygen so that the incoming air to the combustion process is at least 22% by volume and up to 35% by volume oxygen.

[0023] The overall process is shown in FIG. 1. As shown in that Figure, glass is melted in melting pot 11 and extruded from bushing 2 through a plurality of spinnerets 3 into a series of primary filaments 4. The primary filaments are gathered by pull rolls 6 and 8 into guide rolls 7 and 9 of fiber guide 9.

[0024] A burner 10 is fed by pipe 11 with a fuel/air mixture from conventional gas train or premix device 12, which mixes(combines) ambient air from ambient air inlet 13 and fuel from fuel inlet 14. Oxygen analyzer 15 analyzes the oxygen content in the gas train or premix device 12 and
sends signals to controller 16 through line 17. The controller 16, in turn, sends signals through line 17a to adjust the flow of oxygen through pipe 18 from control valve 19 of a “package” oxygen generator 20.

The burner 10 combusts the air/oxygen/fuel mixture from pipe 11 into a flame in former tube device 21 where the flame draws and attenuates the primary filament 4 into fibers 22 (the fiberizer unit). Optionally, a conventional binder material may be sprayed onto the fibers by binder sprays 23. The burner 10 shown in the figure is shown as a generic burner, but it is preferred that the burner be a slot burner as described in U.S. Pat. No. 2,569,699. That patent also describes the details of the process summarized above, and the disclosure of that patent is incorporated herein by reference for those details.

The fuel used in the process may be any gaseous, oxidizable fuel, but hydrocarbon fuel, e.g., natural gas, liquefied petroleum gas, and the like, is preferred for obvious reasons. The oxygen may be pure oxygen, but somewhat impure oxygen, such as that produced by the “package” units, described above, is preferred due to the economics. The oxygen, however, should be substantially pure oxygen, e.g., the oxygen stream should consist essentially of oxygen, and especially the oxygen stream should be at least 70%, e.g., 75% and especially 85% oxygen. This avoids uneconomical amounts of waste gases being heated to the fiberizing temperatures, for the reasons explained above. However, pure oxygen is quite expensive and less than pure oxygen, as identified above, is preferred.

Of course, care should be exercised when introducing oxygen into a fuel/air mixture, and to that end, it is preferred that the oxygen be introduced into the mixture by way of special spargers. One established way of such introduction is that of introducing the oxygen into the air stream prior to introducing the resulting oxygen/air mixture into the fuel. Special spargers are available for introducing oxygen into an air stream and one sparger that is preferred is that made by AIR LIQUID, and designated as the OXYNATOR TM. These devices are of the type known as the swirl-type sparger, which introduces the oxygen at the center of an air pipe and imparts spin in order for mixing of the oxygen and air to occur. This avoids high oxygen concentrations near the pipe wall and avoids a possible danger.

FIG. 2 diagrammatically illustrates the foregoing arrangement. As shown in that Figure, air flowing in air inlet pipe 13 is mixed in sparger 25 with oxygen flowing in oxygen inlet pipe 18. The mixture is then passed through inlet pipe 13, again to gas train or premix device 12, as shown in FIG. 1.

By using the oxygen enhanced process in such a way as to make superior quality fiber, as described above, hand sheets made of fibers from that process have at least a 16% better tensile strength, g/in., and about at least a 28% increase in double fold tensile strength, g/in. This latter tensile is particularly important since it more relates to necessary properties for pleated (folded) filters. This shows that the present process provides substantially improved and superior fibers and papers produced therefrom. However, the use of the oxygen enhanced process could also be optimized to make a less costly product with quality similar to standard glass fibers by taking advantage of the thermal efficiencies offered by the hotter, higher velocity enriched flame. Further, since the present process avoids both the “lean” and “rich” conditions of the prior art, as explained above, the problems, including the economic problems thereof, are avoided and, thus, the present invention provides more cost effective fibers.

Of course, the process of the invention could be used for making micro fibers from materials other than glass, e.g., inorganic fiber forming materials such as various metals and organic fiber forming materials such as thermoplastic polymers, but it is especially useful for producing glass micro fibers, as fully described above.

1. A process for producing improved, superior and more cost effective glass micro fibers, wherein molten glass in filament form is attenuated into glass micro fibers by gasses of a combusted mixture of air and fuel,

the improvement comprising introducing into the mixture a gas stream containing at least 70% by volume of oxygen.

2. The process of claim 1, wherein the gas stream contains at least 75% oxygen.

3. The process of claim 2, wherein the percentage of oxygen is at least 85%.

4. The process of claim 3, wherein the gas stream consists essentially of oxygen.

5. The process of claim 4, wherein the gas stream consists of oxygen.

6. The process of claim 1, wherein the oxygen stream is produced by a packaged oxygen generator.

7. The process of claim 1, wherein the oxygen is introduced into an air stream, which air stream is in turn introduced into the fuel by a sparger.

8. The process of claim 7, wherein the sparger is a swirl-type sparger.

9. The process of claim 1, wherein after introduction of the gas stream containing the oxygen into the mixture, the mixture is between 22 and 35% by volume oxygen.

10. A fiberizer apparatus for producing improved, superior and more cost effective glass micro fibers, comprising:

   (1) a premix device (12) for combining ambient air flowing from an ambient air inlet (13) and fuel flowing from a fuel inlet (14);

   (2) an oxygen analyzer (15) for analyzing an oxygen content of the combined air and fuel in premix device (12);

   (3) an oxygen generator (20) for generating oxygen and flowing the generated oxygen to the premix device (12) to form a mixture of oxygen/air/fuel;

   (4) a controller(16) for adjusting the flow of oxygen from generator(20) to the premix device(12) in response to signals generated by oxygen analyzer(15) so as to provide the mixture with at least 22% by volume oxygen; and

   (5) a burner (10) for combusting the mixture into a flame in a former tube device (21) for drawing and attenuating primary filaments (4) of molten glass into glass micro fibers (22).

11. The apparatus of claim 10, wherein the flow of oxygen from generator (20) is introduced into the ambient air flowing into premix device (12).
12. The apparatus of claim 11, wherein the flow of oxygen is introduced into the ambient air by a sparger (25).

13. The apparatus of claim 12, wherein the sparger is a swirl-type sparger.

14. The apparatus of claim 10, wherein the oxygen generator is a packaged oxygen generator.

15. The apparatus of claim 14, wherein the packaged oxygen generator is near the fiberizer apparatus.

16. Improved glass micro fibers which can be formed into a paper with at least a 16% better tensile strength.

17. The fibers of claim 16, which can be formed into a paper with at least a 28% increased double fold tensile strength.

18. A paper made of the fibers of claim 16.

19. A paper made of the fibers of claim 17.

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